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Search for narrow high-mass resonances in proton-proton collisions at 8 TeV decaying to a Z and a Higgs boson

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We present a search in the CMS detector for an exotic high-mass and narrow resonance decaying into a Z and a Higgs from standard model in the final state with a pair of tau leptons and a pair of quarks. We analyze 19.7/fb of integrated luminosity of proton-proton collisions at $\sqrt{s} = 8$ TeV from LHC. In the resonance mass range of interest ($0.8 - 2.5$ TeV), the Z and Higgs bosons are produced with large momentum compared with their masses, which implies that the final products of the two quarks and the two tau leptons must be detected within a small angular separation. Jet substructure techniques are used to identify the boosted Z boson decaying hadronically and a modified approach is considered to reconstruct very collimated pairs of tau leptons from boosted Higgs decay. From a combination of all possible decay modes of the tau lepton, heavy spin-1 resonances production cross sections are excluded at 95% C.L. in a range between 0.9 and 27.8 fb, depending on the resonance mass.

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We search for resonances in the mass range of $0.8-2.5$ TeV decaying to ZH, where the Z boson decays to $q\bar{q}$ and the Higgs (H) boson decays to $\tau^+\tau^-$. We analyze 19.7/fb of integrated luminosity of proton-proton collisions at $\sqrt{s}=8$ TeV with CMS detector [1] at LHC. We investigate all the decay modes of the tau lepton and assume that the natural width of the resonance is negligible in comparison to the experimental mass resolution, which is between 6% and 10% of the mass of the resonance, depending on the mass.

The theoretical model used as benchmark in this analysis is described in Ref. [2]. In this model a heavy $SU(2)_L$ vector triplet containing neutral (Z') and charged (W'$^{\pm}$) spin-1 states is defined in a phenomenological Lagrangian (HVT framework). This simplified model can be interpreted in classes of models where the new physics sector is either weakly coupled [3], or strongly coupled, e.g., in minimal composite Higgs models [4]. The heavy resonances production cross sections and branching fractions ($\mathscr{B}$) in the HVT framework depend on the new physics scenario under study and can be characterized by three parameters in the phenomenological Lagrangian: the strength of the couplings to fermions c_{F}, to the Higgs c_{H}, and the self-coupling g_{V}. In the case of a strongly coupled sector, the new heavy resonance has larger couplings to the W, Z, and H bosons, resulting in larger branching fractions into diboson final states.

In this analysis, the directions of the pair of particles from Z and H boson decays are separated by a small angle. This feature is referred to as the "boosted regime" or "boosted topology". The $Z \to q\bar{q}$ results in the presence of one single reconstructed high-energy jet, called a "Z-jet" or "fat-jet". From the high-momentum $H \to \tau^+\tau^-$, it is detected two narrow jets separated by a small angle and with a low charged particle multiplicity, since most of the τ decays are in one or three charged tracks plus some neutral hadrons (one or three prongs). These signal features are differentiated from the main background components (mostly composed by quark/gluon initiated jets) looking into the substructure of the jets in the final state.

The event selection is divided in two parts: online and offline. The online corresponds to the trigger selection with requirements on the hadronic activity of the event, most of the time triggered by the Z-jet (efficiency above 99% after signal-like offline selection). The offline selection has requirements on missing transverse momentum and number of b-tagged jets per event, on the substructure and mass of the Z-jet, and on the kinematics of the pairs of boosted tau leptons from the Higgs decay. The offline selection depends on the decay mode of the pair of tau leptons and reaches higher efficiencies in all-leptonic channels (both tau leptons decaying into muons or electrons) varying between $20-60\%$. In semileptonic channels (one τ decaying hadronically) and all-hadronic channels (both tau leptons decaying hadronically) the offline selection efficiencies vary between $20-40\%$.

After reconstructing and indentifying the ZH candidates, the number of observed events are compared with the predictions of the standard model background and signal events. No statistical significant deviations from the expected background is observed and upper limits are set in the heavy resonance production cross section. In Fig. 1 it is shown experimental limits on the cross section as a function of the mass of the reconstructed pair of bosons and a scan in the parameter space of the HVT framework. A detailed description of the analysis can be found in Ref. [5].

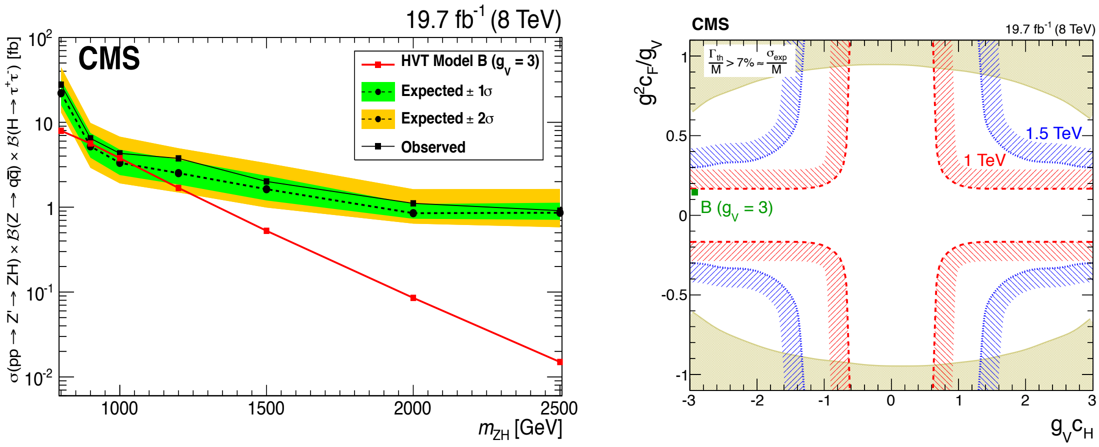

Figure 1: Left: expected and observed upper limits on $\sigma(Z') \cdot \mathscr{B}(Z' \to ZH)$ with Z decaying hadronically and Higgs decaying into a pair of tau leptons. Green and yellow bands correspond to ± 1 and $\pm 2\sigma$ variations on the expected upper limit, respectively. Right: exclusion regions in the plane of the HVT framework coupling constants $(g_V c_H, g^2 c_F / g_V)$ for two resonance masses, 1.0 and 1.5 TeV. The boundaries of the regions of the plane excluded by this search are indicated by the dashed and dotted lines, and associated hatching. The areas indicated by the solid line and solid shading correspond to regions where the theoretical width is larger than the experimental resolution of the present search and thus the narrow-resonance assumption is not satisfied. The point B corresponds to $g_V = 3$ and $c_F = -c_H = 1$ and it was used as benchmark model for the analysis.

References

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